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Measuring the speed of gravity in short distances: improving signal strength.

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Abstract.

In order to investigate the speed of gravitational signals traveling in air and through a different medium a experiment is proposed. The experiment contains 2 masses vibrating (emitters), the masses will emit a periodic tidal gravitational signal and one sapphire device that behaves as a detector is located between the two vibrating masses. This detector is suspended in vacuum and cooled down to 4.2 K will. The vibrational amplitude of the sapphire detector is measured by a microwave signal with ultra=low phase-noise that uses resonance in the whispering gallery modes inside the detector device. Sapphire has quite high mechanical and electrical Qs which implies a very narrow detection band thus reducing the detector sensitivity but amplifies the phase difference of the signal coming from the emitters. With the aid of a finite element program the normal mode frequencies of the detector can be calculated with high precision. The results show that to improve the sensitivity of the experiment is necessary to improve the signal strength. A new emitter is proposed then the new best operational frequency is calculated showing a better design for the experiment.

1 Introduction

The detection of Gravitational waves (GW) that were theoretically predicted by Albert Einstein's General Theory of Relativity taking almost one hundred years of development and using interferometric GW detectors [1]. After this observation others have been made including the first observation on of a binary Neutron Stars merger [2, 3, 4], this event was the first multimessenger detection using GW, the event was a Hipernova and was detected also by gamma-rays in the form of a burst. This is the GW170817 event, observed on August 17, 2017, the event was caused by the merger of two neutron stars, confirmed by the detection of gravitational waves by the LIGO/Virgo detectors and a gamma-ray burst detected by Fermi and INTEGRAL shortly after. This single event provided strong evidence that short GRBs (gamma-ray bursts) are produced by neutron star mergers and also demonstrated the creation of heavy elements like gold and platinum in these mergers, marking a new era in astrophysics. This event was also used to observe the speed of these GWs, this was done by the near-simultaneous detection of gravitational waves and gamma-rays from this event, showing that both signals arrived within 2 seconds of each other after traveling for 144 million years (this distance was measured as the optical counterpart of the event was identified) [5].

Some of the authors are part of a research group in Brazil to study gravity [6, 7]. The group built the spherical resonant-mass GW detector Mario Schenberg [8].

1.1 This paper approach

This paper approach is different, the approach is to measured the speed of a tidal gravitational field as the distribution of mass change with time. This approach is presented and modeled for the this time in [9].It was better explained in [10]. The sensitivity of the experiment, para a gravity speed equals to the speed of the light, is calculated to the be of one part in one million, considering that the position of the mechanical parts can be measured with a precision of one part in one million [11].

The change of masses is caused by the vibration of device called the emitter, it causes tidal forces in another device called detector. In the first approach there are formed by 3 connected bars which the vibration modes can be seen in figure 1. SolidWorks simulation was used to calculate the vibration modes of the emitter and the detector devices build the geometries and analyze the mechanical response of the components. A fine mesh was applied to ensure convergence.

The experiment uses sapphire bars connected, the vibration of these bar can be measured by microwaves, as the sapphire bars works as microwave cavities [12]. To improve the sensitivity of the experiment it is necessary to increase the bandwidth of the detector device, This is done connecting resonators of similar masses [13]. The three detection modes of the detector can be seen in Figure 1.

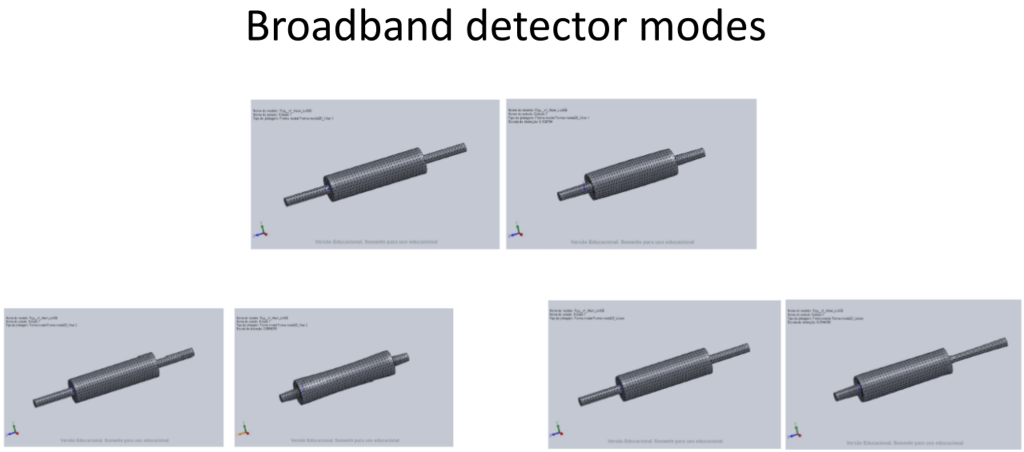


Figure 1: This figure shows the old emitter and detector devices made of sapphire. Source: the authors

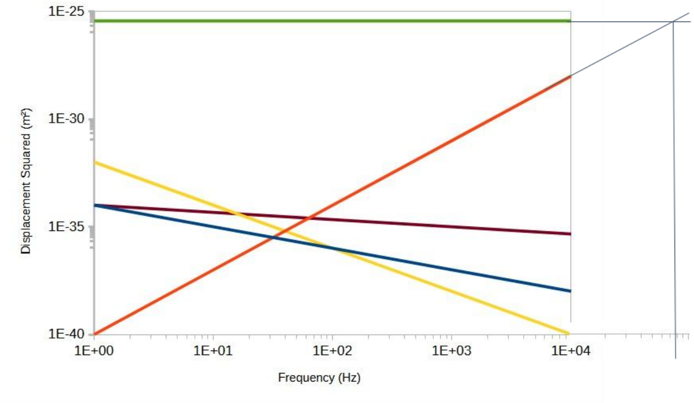
2 Results and discussion

The detector working at that configuration at 5 kHz is too big for the experiment proposal, working with the emitter and detector at 1 meter from each other. To allow it and keep a signal noise ratio of ten (in meters not square) the vibration amplitude of the emitter was increased from a previous configuration [11] to 5 x 10^{-4} m. The graphic with the noise and signal can be see in Figure 2

Increasing a = 5 x 10^{-4} m

(Vibration amplitude of the

bars);



Red line is the detector sensitivity;
The purple line shows the back-action and the electronic series noise;
The yellow line displays the thermal noise;
The green line is the signal generated at the detector;
The blue line shows the quantum limit.

Figure 2: The graphic with the noise and signal amplitudes. Source: the authors

As the sensitivity of the experiment depends on the sensitivity in the determination in the position of the mass of the emitter, a new emitter is proposed and it must vibrate at a frequency close to 10 kHz. The figure 3 shows the proposed emitter and the new signal strength for this design. Figures 4 and 5 shows the two detection modes of the emitter and the detector.

A new design for the emitter and detector

$$\Delta b = \frac{2GMa}{x^3 \omega^2}$$

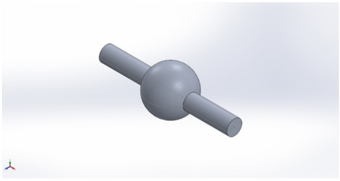


Figure 3: The proposed emitter and detector design and its signal strength. The length of each component is 20 cm, making it 60 cm long. Source: The authors.

3 Conclusion and outlook

The work shows the possibility to measure the speed of gravity in short distances with a signal to noise ratio of about 10 operating at a frequency of around 19 kHz. With a distance of 1 meter, the precision of the measurement is (assuming speed of gravity equal to the speed of light: σ_{cg} 3 x 10^2 m/s around 1 part in 10^6. A new emitter and detector design is been developed to improve better precision in the

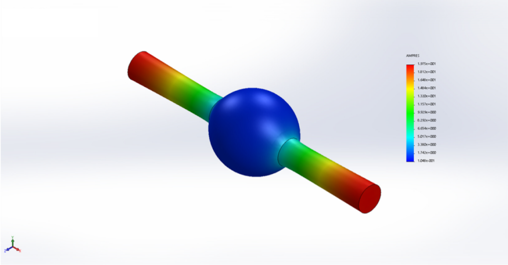


Figure 4: Detection and emitter first detection mode. Vibration frequency of about 8907 Hz. Source the Authors.

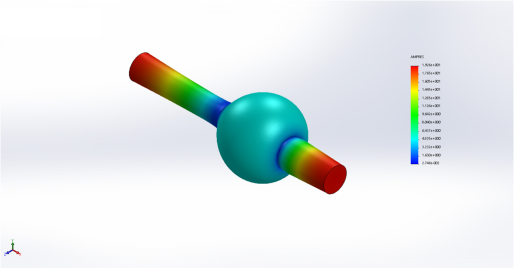


Figure 5: Detection and emitter second detection mode, this is the main mode, as the sphere vibrates.Vibration frequency 10812 Hz. Source the Authors.

determination in the position of the experiment parts. The seismic noise was not considered as it can be minimised by making a suspension that isolates the seismic noise in the correct factor and running the experiment underground. To avoid charge to be built in the experiment, the devices can be submitted to ultraviolet light. It is also necessary to compensate, the time that the microwave signal stays inside the cable, but this speed is know as the length of the cables.

There are some modes of lower frequencies that needs to be studied to check if they interacts with the suspension.

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